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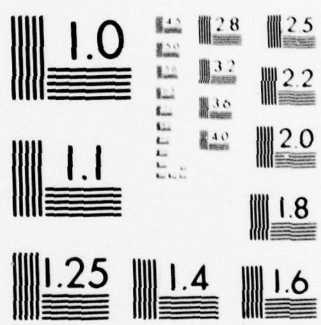

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FIFTH EUROPEAN SPECIALIST WORKSHOP ON
MICROWAVE ACTIVE SEMICONDUCTOR DEVICES

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6 MARCH 1979

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The report is a brief description of subjects discussed at a workshop attended by approximately fifty individuals engaged in work on microwave semiconductor devices and/or their use in circuits.

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FIFTH EUROPEAN SPECIALIST WORKSHOP ON
MICROWAVE ACTIVE SEMICONDUCTOR DEVICES

The US and Japan are not alone in efforts aimed at replacing microwave tubes with solid-state devices. Europe has been active in this area for a long time. In fact, Dr. Cyril Hilsum of the Royal Signal and Radar Establishment (RSRE), Malvern, UK, is looked upon by many as the godfather of much of the device-oriented work with III-V compounds in the West. Moreover, the Plessey Company Ltd. currently claims to fabricate the best low-noise microwave gallium arsenide field effect transistors (GaAsFETs).

To further this work, small groups of researchers have met annually since 1972 (except for 1976) to discuss problems and progress in this field. This is a brief report on the latest of such meetings, the 5th Specialist Workshop on Active Microwave Semiconductor Devices, held in October 1978. The Hotel Des Bains, on Lido di Venezia, one of the islands in the bay at Venice, was ideal for this workshop. Since the tourist season had concluded six weeks earlier there were no diversions on the island to detract from participation in the workshop. On the other hand, nearby Venice kept spouses happily occupied during the day and beckoned to everyone to enjoy its treasures after the working sessions. Perhaps the only hitch was that a few of the participants were delayed for several hours by one of the so-called hiccup train strikes that sometimes occur in Italy.

Organized on a rather informal basis by individuals from several countries and sponsored this year by Centro Informazione Studi Esperienze (CISE) SpA, an Italian research organization in Segrate, near Milan, and by the US Army European Research Office, the workshop was attended by 54 individuals. The UK contingent was the largest, followed closely by that of Italy, with smaller groups from West Germany, France, Ireland, Hungary, Sweden, Japan and Austria. Except for the writers, the only representive from the US was Dr. Daniel R. Ch'en, of the Rockwell International Science Center, Thousand Oaks, CA, whose group is well known for its work on ion implanted GaAsFETs with Schottky barrier gate structures (MESFETs).

Among the organizers were J. Magarshack of LEP, the Philips-owned organization in Paris; H. Thim, of the Technical Univ. in Vienna; H. Hartnagel, who had just joined the Technical Univ. in Darmstadt, FRG, after a number of years at the Univ. of Newcastle upon Tyne, UK; P. Weissglas, of the Royal Institute of Technology, Stockholm; and G. Fabry and V. Svelto, of CISE SpA. Not all groups working in the field in Western Europe were represented at the workshop. For example, it is known that AEG-Telefunken is developing microwave transistors, but no representative from that firm was present. Subjects discussed were Material and Device Technology, Diodes, MESFETs, MOSFETs, and Circuits. It could be argued that these subjects were already well covered

in the European Microwave Conference and the European Solid State Device Research Conference; so "Why have a specialist meeting?" According to the organizers, the more formal conferences are generally limited to papers dealing with finished work; the workshop allows a discussion of work in progress. In addition, the workshop had papers both on devices and how they are used in circuits, while the two conferences discussed either one topic or the other, but not both. In addition, the multiple sessions of the more general conferences, which serve to inform on a number of subjects, do not allow the concentration possible in a workshop.

Most of the papers presented could be termed "state-of-the-art." The one real exception, and perhaps the most significant because it pointed the way toward the future, was a paper by G. Salmer (Université de Lille, Villeneuve d'Ascq, France) entitled "Simulation of very short gate FET including steady state electron dynamics effects." With the higher packing densities of devices on a chip and higher speeds of device operation, a point is reached eventually at which the transit time of electrons through a channel becomes of the order of the electron energy relaxation time. This means that the average electron velocity at a given time depends not only on the electric field but on the average electron energy as well. Not only is the ordinary concept of conductivity then no longer valid, but overshoots in electron velocity above saturation values become possible. Moreover, since only a small number of electrons exist in a channel at any one time, diffusion effects cannot be calculated in the usual classical manner. Specific conclusions from this paper were that for an FET the ratio of transconductance to gate capacity, g_m/C_g, varies as the reciprocal of gate length and that when relaxation effects are accounted for, g_m/C_g is increased. Results were given for Si and GaAs, but without taking electron transfer in GaAs into account.

Among the other papers, emphasis was on the following topics: (1) Oxygen injection during vapor phase epitaxy (VPE) growth of GaAs for MESFETs (H. Bruch *et al.*, Technische Hochschule, Aachen, FRG). Said to suppress Si activity caused by the quartz walls, the technique allows growth of high resistivity buffer layers and produces layers of mirror-like finish. (2) The effect of deep traps in GaAs and InP on the noise in mixer and detector diodes (A.J. Grant, RSRE). Using the deep level transient spectroscopy (DLTS) technique of applying a pulse of forward current to a cooled diode and measuring the change in capacitance, Grant found a number of deep traps in InP. These traps are responsible for low-frequency noise. (3) Ion-implanted GaAsFETs (N. Bujatti, Selenia SpA, Rome). This work demonstrated that microwave MESFETs are being fabricated in Italy, but the work seems not as advanced

as at Rockwell International. (4) Improvements in performance of BARITTs by ion-implantation (B.M. Armstrong *et al.*, Queens Univ., Belfast, N. Ireland). BARITTs are negative resistance devices that find their use in self-oscillating low-noise microwave mixers. They compete with Gunn devices, are found to be lower in noise than the latter, and are less influenced in oscillating frequency by temperature changes. But they require a higher operating voltage and have a negative resistance that is more temperature sensitive than that of the Gunn devices. (5) Papers on the use of IMPATTs and TRAPATTs in oscillator and amplifier circuits (P.W. Huish, Post Office Research Centre, Ipswich, UK; Y. Ogita, Ikutoku Technical Univ., Japan; P.L. Booth *et al.*, Philips Research Laboratory, Redhill, Surrey, UK; and A.M. Howard, The Plessey Company, Ltd., Caswell, UK). During the discussion it was pointed out that TRAPATTs, though more complicated in circuitry, have a faster turnoff than transistor oscillators. (6) Use of InP Gunn oscillators, to give peak output of 59 W from 4 diodes at 17 GHz, at duty cycle of 0.01 and with efficiency of 12.7% (J.E. Pattison, RSRE, Malvern, UK). It was pointed out during the discussion that these devices have a positive temperature coefficient and therefore the possible danger of burnout by thermal runaway. (7) A self-aligning technique that yields sub-micron structures by photo-resist control (G.P. Donzelli, CISE SpA, Milan). Though very well done, other techniques requiring more expensive equipment have, however, already achieved the same resolution. (8) The technique orginally proposed by Matsushita Co. in 1975 of fabricating a GaAs/$Ga_{1-x}Al_x$As gate electrode on an n-type GaAs active layer, to produce an enhancement type FET. (K. Mause, Fernmeldetechnisches Zentralamt, Darmstadt, FRG). This technique has the advantage of a built-in voltage of 1.5 V, compared to 0.3 V for MESFETs, and 0.8 V for ordinary JFETs; will therefore be much less subject to errors for logic circuit operation. (9) Use of a feedback technique to maintain a constant 800-mW output ($\pm\frac{1}{2}$ dB) from a 3.2 to 3.7 GHz saturated GaAsFET amplifier over temperature range 10°C to 70°C (T. Bambridge, the Plessey Company, Ltd., Caswell, UK). The technique was to use a silicon diode to sense the temperature and a feedback circuit to alter the bias voltage on the GaAsFET. (10) Silicon MOSFETs for operation to X-band or for use in normally-off high speed logic circuits (U. Niggerbrugge *et al.*, and C. Tsironis *et al.*, Technische Hochschule, Aachen, FRG). (11) GaAs MOSFETs and their technology—review of present position and future prospects (H. Hartnagel, one of the organizers of the Workshop). As is well known, Gigabit logic and microwave amplifiers for the higher frequencies require the use of compounds such as GaAs and InP. Commercially made GaAs devices currently available are of MESFET type. MOSFETs, or, in general, MISFETs (Metal-Insulator-Semiconductor FETs) would have the advantage of admitting

"normally-off" technology. In addition, they would have a larger signal capability because the low Schottky barrier of MESFETs limits signal intensity. The fringing capacity of MISFETs would also be less deleterious and would therefore allow operation at higher frequencies.

The problem, according to Hartnagel, is that no one has consistently been able to fabricate good insulating layers with satisfactory interface properties on GaAs and InP, although several laboratories have been trying. No easily-applied insulator similar to SiO_2 on silicon has yet been found. Hartnagel reviewed the efforts aimed at making good insulating layers as well as the techniques used for characterization of what has been fabricated. He discussed not only his own work but also that of such groups at Fujitsu in Japan, the Naval Ocean Systems Center, San Diego, CA, and Wright Patterson Air Force Base, OH. To summarize this work, it can be said that GaAs MISFETs have been constructed and that some interesting results have been obtained. However, it is still necessary to find ways of reducing charge trapping near the interface between the semiconductor and the insulator. Results suggest the difficulties are associated with non-oxidized arsenic at the interface. Present thoughts are to use a suitable non-native oxide on top of a thin intermediate layer of Ga_2O_3. Some progress in this direction, in which a layer of Al_2O_3 was deposited on a gallium-rich oxide film on GaAs, was reported in a separate paper by S.J. Hannah, a student of Hartnagel at Univ. of Newcastle upon Tyne, UK. (12) There were also several papers dealing with other active microwave circuits. An example was a paper in which a method of broad-banding of IMPATT circuit by reactive compensation was discussed (C.S. Aitchison *et al.*, Chelsea College, Univ. of London, UK). Increase in bandwidth from 250 MHz to 800 MHz was reported, with additional benefit of reduction of intermodulation products.

While we have not reviewed every paper that was presented at the workshop we believe that this report lists the general topics that were discussed in some detail.

The next workshop in the series is now slated for May 1980, at Bad Dürkheim, FRG. Prof. E. Hesse, Forschungsinstitut der Deutschen Bundespost, Postfach 5000, 6100 Darmstadt, FRG, is listed as Chairman of the Organizing Committee.